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A Performance-Based Incentive Program for Asphalt Pavement

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A Performance-Based Incentive Program for Asphalt Pavement

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16. Abstract

The Nebraska Department of Roads (NDOR) currently has an incentive system which rewards contractors for quality of materials and workmanship documented during the construction of flexible pavement. The system presented in this report rewards contractors for producing flexible pavement with good long-term performance characteristics. After studying pavement warranties and long-term quality control measures used by other agencies plus consulting with the NDOR and several pavement contractors, researchers proposed an incentive system for flexible pavement that is based upon two performance measures, rutting and flushing. Three years after construction, flexible pavement with rutting less than 4 mm and flushing less than twenty percent would qualify for a monetary incentive. Three projects built in 2002-03 were subsequently analyzed where construction quality incentives ranged from 3.7% to 5.7% were paid. Based upon rutting data measured annually by the NDOR, only one of these projects would have qualified for the proposed incentive. A suggested minimum for the incentive was established as 6%, since an incentive paid three years later will have to exceed the incentive paid immediately after construction to interest contractors. A quality incentive program of this type has the potential to provide many of the benefits of pavement warranties, best value contracts and performance-based contracting procedures with significantly less legal entanglements.

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CHAPTER ONE
INTRODUCTION

The current procurement system for asphalt pavement used by the Nebraska Department of Roads (NDOR) utilizes a competitive sealed proposal with the contract awarded to the lowest responsible bidder. Cost control continues to play a fundamental role throughout the pavement construction process. The contractor purchases materials from a supplier, who is also often the lowest bidder. As paving materials move through the contractor's equipment, binder and aggregate are tested by the contractor, by NDOR personnel and/or by independent quality control technicians. Deficiencies in workmanship or material quality result in monetary penalties levied against the contractor. The contractor often passes these penalties onward to the material supplier.

NDOR currently has in-place a system of incentives to reimburse contractors for pavement quality based upon indices measured at completion of construction. For asphalt pavement, problems resulting from materials or construction techniques used often do not become apparent until one to three years after construction has been completed. The system currently used by the NDOR lacks incentives to encourage use of materials or construction techniques which might significantly improve the long-term quality of asphalt pavement.

This research investigated the advantages of creating a system of incentives to reward contractors for producing asphalt pavement with good long-term (one to three years) performance characteristics. It evaluated several pavement performance indices to determine which were most reflective of long-term asphalt pavement performance and examined the concept of awarding specific monetary incentives to pavement contractors based upon levels of performance indicators at various points during pavement lifespan.

This research also analyzed various existing and experimental incentive programs, with the objective of developing one or more performance-based incentives that the NDOR could use for contractors providing asphalt pavement to the State of Nebraska. Since the NDOR already has an incentive system keyed to specific indices measured immediately after completion of construction, the proposed incentive program is based upon indices measured later in pavement life. Various quality indices (International Roughness Index, rutting, cracking, etc.) measured annually by the NDOR were evaluated for their potential to serve as indicators of pavement quality one to three years after construction.

The performance incentive system proposed allows contractors to receive full contract payment for pavement built to construction specifications. The system will subsequently provide an additional monetary incentive at a specified interval to contractors who produce pavement that continues to meet or exceed established quality standards.

CHAPTER 2
INFORMATION SEARCH

Performance measures consist of assessment data that strongly, directly, or quantitatively reflect the degree to which specific results meet the needs and expectations of the customer. These measures are often compared to goals or benchmarks, so remedial actions can be initiated when benchmarks are not being met. Performance indicators, on the other hand, are data that suggest general alignment of results with customer goals. Indicators are typically direct or surrogate measures for the actual performance characteristics of interest. Indicators can be useful in identifying trends in overall performance, as well as for actual comparison to a desired goal. Performance measures can be aggregated from local to state to regional to national levels. Some performance measures may even at allow an agency to be compared with other agencies, if a measure based on cost is used (Richter 2004).

2.1 How Does the NDOR Measure Pavement Quality?

The NDOR measures quality of asphalt pavement by the use of means and method specifications, the application of quality assurance specifications and through NDOR evaluations of quality at the completion of construction. Quality of asphalt pavement is not measured by NDOR through performance related specifications or warranties (OPA 2006).

The NDOR conducts almost continuous assessment of quality throughout the lifetime of a pavement. Numerous indicators are measured and recorded annually for each section of highway throughout the network. The NDOR's Supplemental and Standard Specifications for Highway Construction (2007) lists some of these indicators including:

<u>Roughness (IRI):</u> The roughness or International Roughness Index (IRI) is a measure of pavement smoothness commonly recorded in vertical millimeters per lateral meter.

Cracking Index: This is a rating value expressed as a percentage, which is used to quantify the amount of cracking based on the severity and extent noted during a visual inspection.

Transverse Cracking: The transverse/thermal-cracking index is expressed as an index on a scale of 0 to 100, with 0 being the best condition and 100 the worst. The index reflects the severity and extent of transverse cracking on a bituminous pavement.

Rutting: The average rut depth of both wheel paths measured with a pavement profiler commonly recorded in millimeters. Rutting is characteristic of bituminous pavements.

PSI: The Present Serviceability Index or PSI. This is a numerical value indicating the ride quality of the pavement. PSI is a function of roughness IRI, cracking, and rutting. PSI is evaluated on a scale from 0 to 5, with 0 characterizing the worst condition and 5 the best.

Current NSI: The Nebraska Serviceability Index is recorded as value on a scale from 0 to 100, with 0 the worst and 100 the best condition. The number represents the relative condition of the pavement at the time of measurement. NSI is used to develop remaining years of pavement life.

Percent Joint Seal: A factor measured for concrete pavement denoting the extent of joint seal failure at a sample site.

Faulting: The average displacement at the longitudinal and transverse joints, commonly measured in millimeters.

Specific indicators for particular pavement types falling below prescribed levels trigger various repair or rehabilitation practices under the NDOR's pavement management plan (NDOR 2005).

2.2 Current NDOR Construction Incentives/Disincentives

Current NDOR quality incentive programs for pavement are based upon pavement smoothness and quality of materials immediately after construction has been completed. Smoothness provisions can be found in Section 502.08 and Section 1028 of the NDOR's Supplemental and Standard Specifications for Highway Construction. Examples of payment adjustment factors for smoothness are illustrated in Table 1, while examples of payment adjustment factors for materials and workmanship are shown in Tables 2-5.

If the initial profile index is 10.0 in/mi or less and bump removal is required, a second profilogram is taken after the bumps are removed (Table 1). The percent of pay for a profile index is then based upon the second profilogram subject to the limitations that follow. If the initial profile index exceeds 7 in/mi, then, except for total removal and replacement, the maximum percent of pay after bump removal is limited to 100 percent. Percent of pay is based on a second run of the profilogram after bump removal. The work of smoothness testing is paid for at the lump sum unit price specified in the contract. This price is considered to be full compensation for all smoothness testing as set forth in the specification (NDOR 2007)

Table 1 – The NDOR's Payment Adjustment Schedule for Asphalt Pavement Smoothness.

Payment Adjustment Schedule	
Profile Index Inches Per Lane Mile	**Percent of Contract Prices**
0 to 2.0 inches	105.0
More than 2.0 to 4.0 inches	102.0
More than 4.0 to 5.0 inches	101.0
More than 5.0 to 7.0 inches	100.0
More than 7.0 to 8.0 inches	98.0
More than 8.0 to 9.0 inches	95.0
More than 9.0 to 10.0 inches	90.0
More than 10.0 inches	Corrective work required

(Source: Section 502 – Asphaltic Concrete Pavement Smoothness from NDOR Supplemental and Standard Specifications for Highway Construction)

Pay factor for smoothness of the top layer of asphaltic concrete is determined according to the following formula:

$$PF = \frac{A(1.05) + B(1.02) + C(1.01) + D(1.00) + E(0.98) + F(0.95) + G(0.90)}{A + B + C + D + E + F + G}$$

Where:

A = length of pavement with a profile index of 0 to 2.0

B = length of pavement with a profile index greater than 2.0 to 4.0

C = length of pavement with a profile index greater than 4.0 to 5.0

D = length of pavement with a profile index greater than 5.0 to 7.0

E = length of pavement with a profile index greater than 7.0 to 8.0

F = length of pavement with a profile index greater than 8.0 to 9.0

G = length of pavement with a profile index greater than 9.0 to 10.0

Table 2 illustrates the NDOR's pay factors for asphalt materials. Payment is based upon the top layer of the driving lane asphalt cement and asphaltic concrete. Plan thickness is adjusted according to the schedule and payment criteria shown in Table 3. Adjustments are calculated based on 0.1 mile sections measured by the profilograph (NDOR 2007).

Table 2 – The NDOR's Pay Factors for Asphalt Materials

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Asphalt Materials – Pay Factors		
Pay Factor*	**Specified Property**	
	Upper Limit	**Lower Limit**
1.00	+ 1% to 10%	
0.95	Greater than +10% to +15%	Less than -10% to -15%
0.90	Greater than +15% to +20%	Less than -15% to -20%
0.80	Greater than +20% to +25%	Less than -20% to -25%
0.70	Greater than +25% to +30%	Less than -25% to -30%
0.40 or Reject	Greater than +30%	Less than -30%

* If the resultant pay factor for the material is less than 0.70, the material shall be rejected if not already used. If incorporated in any work which is judged to be unsatisfactory, the material shall also be rejected.

* If the pay factor is less than 0.70 and the material has been incorporated in work which is allowed to remain in place, the pay factor for the material shall be 0.40.

(Source: Table 503.01 A Asphalt Materials – Pay Factors from NDOR Supplemental and Standard Specifications for Highway Construction)

Table 3 – The NDOR's Applicable Properties for Asphalt Pavement

Applicable Properties						
	Asphalt Cement		Asphaltic Oil		Emulsified Asphalt	
Property	**Viscosity Grade**	**Penetration Grade**	**Original Material**	**Distillation Residue**	**Original Material**	**Distillation Residue**
Viscosity	X[1]		X		X[3]	X
Penetration	X	X[1]		X		X[2]
Distillation to 435°F			X			
Distillation to 500°F			X			
Distillation to 600°F			X			
Percent Residue			X		X	
Float Test						X
Absolute Viscosity						X
Softening Point						X

[1] Original material and thin film residue.

[2] Penalties cannot be based on tests made on Residue by Evaporation.

[3] No penalties will be assessed if more than 1 day has elapsed between the sampling and the testing of the material.

(Source: Table 503.01B Applicable Properties from NDOR Supplemental and Standard Specifications for Highway Construction)

Tables 4 and 5 illustrate specific NDOR material pay factors which can serve as incentives or disincentives. Pay factors based upon pavement density attempt to measure quality of both materials and workmanship (NDOR 2007).

Table 4 – The NDOR's Schedule for Acceptance - Density of Compacted Asphaltic Concrete (First Lot)

Acceptance Schedule Density of Compacted Asphaltic Concrete (First Lot)	
Average Density (5 Samples, Percent of Voidless Density)	**Pay Factor**
Greater than 90.0	1.00
Greater than 89.5 to 90.0	0.95
Greater than 89.0 to 89.5	0.70
89.0 or Less	0.40 or Reject

(Source: Table 1028.21 Acceptance Schedule Density of Compacted Asphaltic Concrete (First Lot) from NDOR Supplemental and Standard Specifications for Highway Construction)

Table 5 – The NDOR's Schedule for Acceptance - Density of Compacted Asphaltic Concrete (Subsequent Lots)

Acceptance Schedule Density of Compacted Asphaltic Concrete (Subsequent Lot)	
Average Density (5 Samples, Percent of Voidless Density)	**Pay Factor**
Greater than 92.4	1.00
Greater than 91.9 to 92.4	0.95
Greater than 91.4 to 91.9	0.90
Greater than 90.9 to 91.4	0.85
Greater than 90.4 to 90.9	0.80
Greater than 89.9 to 90.4	0.70
89.9 or Less	0.40 or Reject

(Source: Table 1028.22 Acceptance Schedule Density of Compacted Asphaltic Concrete (Subsequent Lot) from NDOR Supplemental and Standard Specifications for Highway Construction)

2.3 The NDOR's Incentive Program for Superpave Asphaltic Concrete

Acceptance and pay factors for Asphaltic Concrete Type SPS are based on compacted in place average density. Acceptance and pay factors for Asphaltic Concrete Type SP1, SP2, SP3, SP4, SP4 Special and SP5 are based on single test air voids, running average air voids, compacted in place average density, and production tolerances pay factors (NDOR 2004). Examples of Superpave production tolerances and acceptance factors are shown in Tables 6 and 7.

When there is a production tolerance pay factor penalty, the penalty percentage is subtracted from the percent pay for single test air voids for each sublot affected. These three individual pay factors are then multiplied by each other to determine a total pay factor for each sublot [(750 tons) (680 Mg)].

When any single test result on the same mix property from two consecutive QC samples falls outside the allowable production tolerances of Table 6, the material represented by these tests can either be accepted with a 20% penalty or rejected at the discretion of the project Engineer (NDOR 2004).

Table 6 – The NDOR's Production Tolerances*

Test	Allowable Single Test Deviation from Specification
Voids in the Mineral Aggregate	- 0.75% to + 1.25% from Min.
Dust to Asphalt Ratio	None
Coarse Aggregate Angularity	- 5% below Min.
Fine Aggregate Angularity	- 0.50% below Min.

*These tolerances are applied to the mix design specification values, not the submitted mix design targets.

(Source: Table 1028.19 Production Tolerances of Superpave Asphaltic Concrete from Section 1028 of the NDOR's Supplemental and Standard Specifications for Highway Construction, revised 3-22-04)

Table 7 – The NDOR's Schedule for Acceptance - Asphaltic Concrete Air Voids

Acceptance Schedule Air Voids - N_{des}		
Air voids test results	**Moving average of four**	**Single test**
Less than 1.5%	Reject	Reject
1.5% to less than 2.0%	Reject	50%
2.0% to less than 2.5%	50% or Reject	95%
2.5% to less than 3.0%	90%	95%
3.0% to less than 3.5%	100%	100%
3.5% to 4.5%	102%	104%
Over 4.5% to 5.0%	100%	100%
Over 5.0% to 5.5%	95%	95%
Over 5.5% to 6.0%	90%	95%
Over 6.0% to 6.5%	50% or Reject	90%
Over 6.5% to 7.0%	Reject	50%
Over 7.0%	Reject	Reject

(Source: Table 1028.20 Acceptance Schedule Air Voids - N_{des} of Superpave Asphaltic Concrete from section 1028 of the NDOR's Supplemental and Standard Specifications for Highway Construction, revised 3-22-04)

2.4 Other Agency's Construction Incentives/Disincentives

Although many proposed roles for performance standards go well beyond current highway construction practices, performance standards for highway construction are nothing new. Because pavement smoothness is widely recognized as important from a standpoint of both user satisfaction (no one likes to drive on a rough road) and long-term performance (smooth roads last longer and are often of higher overall quality than rough roads), performance standards for pavement smoothness have seen widespread use (Carpenter, et al. 2003). Most highway agencies use smoothness specifications of one form or another. These specifications establish target values for smoothness measured using standard engineering test methods that are related to user perceptions. Many agencies include incentives and/or disincentives to encourage achievement of the high levels of smoothness that result in reduced operating costs for highway users and reduced maintenance costs for the owner agencies. Current performance standards for smoothness and the results obtained from specifying performance standards are illustrated by examples from Arizona, Virginia, and Kansas (Richter 2004).

Arizona

For new construction, Arizona has established a target International Roughness Index (IRI) value of 41, with smoothness expressed in inches per mile. Incentives are earned for values below 38 and disincentives are assessed for values in excess of 48. For rehabilitation projects, the target, incentive, and disincentive values vary as a function of highway type, the nature of the work to be performed, and (in some cases) the smoothness of the existing pavement. Target smoothness is 39 to 68, while the thresholds for incentives vary from 37 to 66 (target value minus 2) and the threshold for disincentives varies from 49 to 78 (target value plus 10).

Removal and replacement (as opposed to other corrective actions) is required for smoothness values that exceed the target plus 45. In general, typical pavement smoothness incentives paid by the Arizona DOT average approximately $7,500 per lane mile or approximately $1.00 per square yard. Average contractors in Arizona produce IRI smoothness values in the mid thirties. Some very good contractors consistently achieve IRI smoothness values in the low thirties, with substantial areas often in the twenties (Richter 2004).

Virginia

Virginia has smoothness provisions for new construction and maintenance resurfacing, with smoothness expressed as IRI in inches per mile. For new construction, 100% payment is awarded for an IRI between 55 and 70 inches/mile. Bonus payments are earned for achieving IRI values less than 55 inches/mile and penalties are incurred for IRI values greater than 70 inches/mile, to a maximum of zero payment at IRI values greater than 160 inches/mile. Corrective action is required when the average IRI for a section exceeds 100 inches/mile (Richter 2004).

For maintenance resurfacing, a maximum 10 percent bonus based on the asphaltic concrete (AC) surface cost is possible for interstate highway sections with an IRI less than 45 inches/mile and for non-interstate roads with an IRI less than 55 inches/mile. Additionally, full payment is reserved for interstates with IRI from 55 to 70 inches/mile, while non-interstates must have an IRI between 65 and 80 inches/mile for full payment (Richter 2004).

Unlike new construction projects, most resurfacing projects are tested prior to and after paving. These projects can be either a straight overlay or a mill-and-replace. Before-and-after testing is used to determine the amount of improvement in ride quality. If the contractor is able to improve the quality by more than 30%, the contractor is guaranteed full payment for smoothness.

For new construction, the contractor can receive an incentive of up to five percent based on IRI results. The amount of the incentive is based the total quantity of all asphaltic concrete used. Maintenance resurfacing contracts allow up to a ten percent bonus. This amount is based on the cost of surface layers only. (Richter 2004)

Virginia has been actively using a ride special provision since the late 1990s. Most of the ride data have been collected on maintenance resurfacing projects. With more than 150 projects in 2002, the average IRI on interstates was 60 inches/mile. For non-interstate routes, the average was 67 inches/mile on U.S. routes and 74 inches/mile on State routes. Over the last six years, the average IRI on the interstates has stabilized while ride quality on non-interstate routes continues to improve (Richter 2004). Analysis of the 2003 ride quality is currently being conducted.

In addition to improved ride quality, Virginia has seen other benefits through use of performance based provisions. During the mix-design process, contractors have developed mixes that better balance mix production costs and level of construction effort to achieve good quality field placement. These custom mixes result in better ride, better density, less tendency to segregate, less permeability, and more liquid asphalt for durability. When the ride special provision is applied on a project, more attention to detail is required throughout the paving process. Use of a materials transfer vehicle, continuous feed of material, no stopping of the paver, and proper rolling techniques are examples of techniques employed to improve ride quality. The use of the ride special provision provides monetary incentives to the contractor and longer lasting pavements for the taxpayer (Richter 2004).

Kansas

With smoothness expressed as profile index in millimeters/kilometer (mm/km), Kansas specifications, in general, require an average profile index of 475 mm/km or less per 0.1 km section as measured with a California-type profilograph. (Richter 2004). An exception is made for ramps and acceleration and deceleration lanes. A profile index of 630 mm/km or less is required at these locations. In addition, PCC pavement areas within each section having high points with deviations greater than 7.5 mm and flexible pavement areas within each section having high or low points with deviations greater than 10 mm in a length of 7.5 meters are to be corrected regardless of the profile index. These efforts seem to be working, especially for asphalt pavement. Figure 1 shows a historical summary of pavement smoothness in Kansas. Note the increase in percentage of asphalt pavement with smoothness between 0 and 160 mm/km between 1991 and 2001.

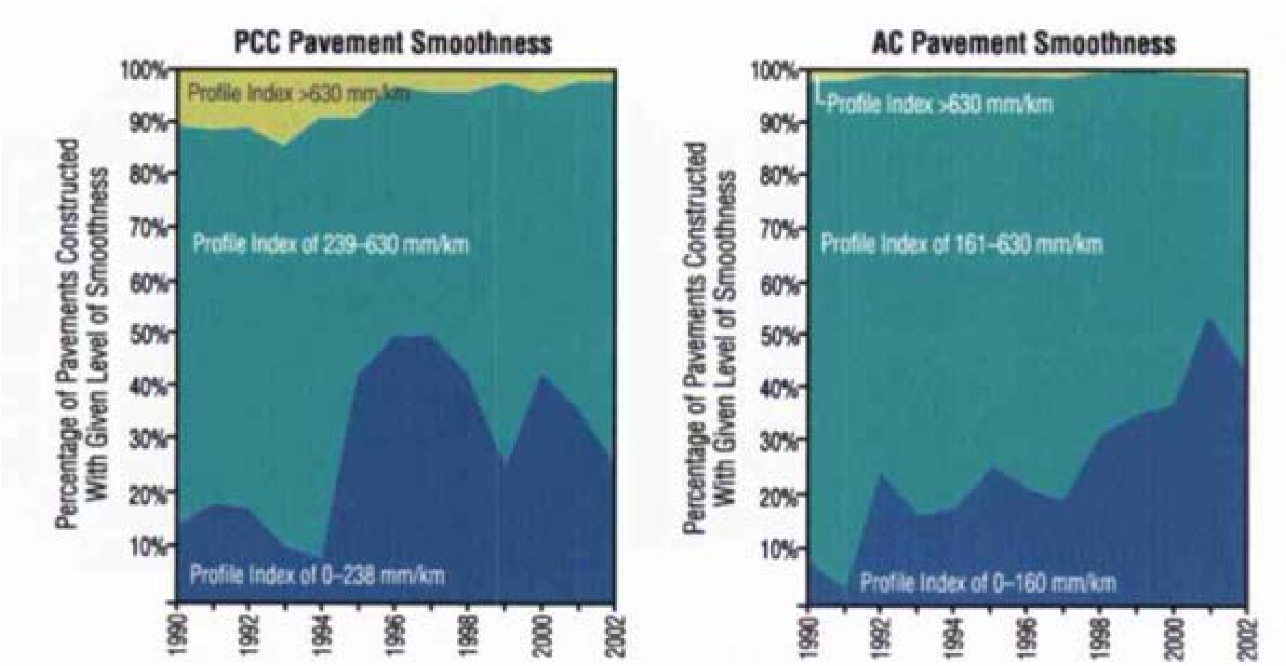

Figure 1 – Smoothness of New Pavement Constructed in Kansas 1990-2002 (Source: Richter 2004)

Pay adjustments are based on the average profile index determined for the sections prior to any corrective work (such as grinding). If the contractor elects to remove and replace the sections or overlay pavement to meet the smoothness specification, pay adjustments are based on the average profile index obtained after replacement or overlay. Table 8 shows the schedule used to adjust payments for flexible pavement quality in Kansas.

Table 8 – Kansas Schedule for Adjusted Payments – Flexible Pavements

Average Profile Index (mm/km per lane per 0.1 km section)	Contract Price Adjustment (per 0.1 km section per lane)
110 or less	+$100.00
111 to 160	+$50.00
161 to 475	0.00*
476 to 630	0.00*

(Source: Richter 2004)

* Correct to 475 mm/km (630 mm/km for ramps, acceleration and deceleration lanes)

Although some fluctuation has occurred from year to year, Kansas has seen a substantial increase in the percentage of pavements built with high levels of smoothness (0 to 240 mm/km for PCC pavements and 0 to 160 mm/km for flexible pavements).

2.5 Management of Long-Term Pavement Performance through Warranties

Warranty specifications are one type of performance specification that has received more attention in recent years. When using warranty specifications, a transportation agency specifies pavement performance only; the contractor must warrant the performance of the pavement over a specific amount of time. This warranty period normally extends two to seven years for asphalt pavements, although some warranties have been written for periods up to twenty years for concrete pavement. During the warranty period, any defects attributable to construction practices or materials are repaired at the contractor's expense. States that have used or are currently using pavement warranties are shown in Figure 2.

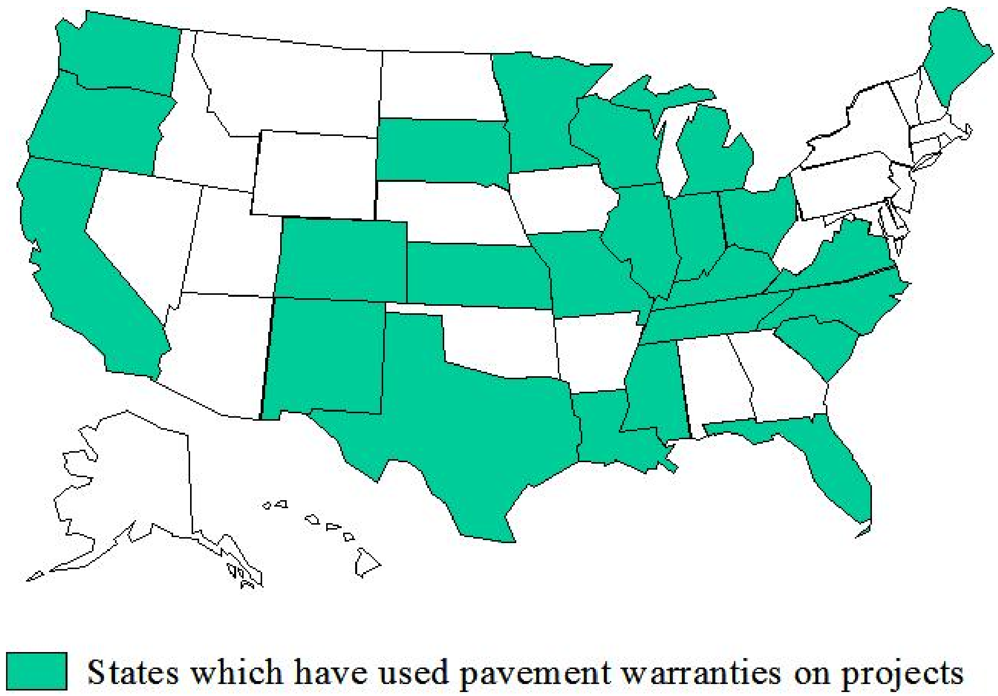

Figure 2 – Use of Pavement Warranties in the United States
(Source: www. fhwa.dot.gov.Pavement/warranty/background.doc
retrieved January 21, 2007)

There are two basic types of construction warranties, materials and workmanship and performance. A materials and workmanship warranty addresses the quality of pavement immediately after construction while a performance warranty addresses pavement quality at some point in time in the future. Performance warranties are typically referred to as a "warranty specification" for pavements (WSDOT 2002).

Almost all HMA pavement construction is covered by a short duration (usually one year) materials and workmanship warranty. This type of warranty assigns risk to the contractor for following transportation agency specifications in regards to materials and workmanship. If a problem or defect is detected within the warranty period, the transportation agency usually uses some type of forensic analysis to determine the cause. If it is determined that specification non-compliance caused the problem, the pavement is repaired at the contractor's expense. If unexpected traffic volume or changed conditions caused the problem, the transportation agency assumes financial responsibility for the repair costs. This type of warranty is almost universal, rarely collected on, and is usually covered by sureties at no additional charge to the contractor.

A performance warranty assigns a longer portion of the pavement performance risk to the contractor. During the warranty period, the transportation agency continues to monitor pavement performance. Throughout the warranty period, any performance below defined limits attributable to construction methods or materials must be remedied at the contractor's expense. Because the contractor assumes greater risk, he/she is allowed to control most aspects of construction.

For specifying transportation agencies, warranties represent progress over end-result specifications because warranties enumerate specific standards for actual pavement performance rather than material characteristics that are only indicative of pavement performance. Table 9 shows an example of performance standards developed by the Indiana DOT. Warranty specifications are more capable of aligning the sometimes competing influences of economic incentives, innovation, customer requirements and pavement quality. This alignment, when achieved, allows market forces and economics, rather than construction specifications alone, to drive pavement quality (NCHRP 2001).

Table 9 - Indiana DOT Pavement Performance Thresholds for a Five Year Warranty Specification

Parameter	**Threshold Value (contractor must take action above this value)**
IRI	2.1 m/km (133 inches/mile)
Rut depth	9 mm (0.375 inches)
Surface Friction	average of 35 but no single section < 25
Transverse Cracking	Severity 2 (as defined by the Indiana DOT)
Longitudinal Cracking	5.5 m (18 ft.) per 152.5 m (500 ft.) section

(Source: Washington State DOT, 2002)

Although warranty specifications are being used in other countries, most notably in Western Europe, they are used only sparingly in the United States for several reasons. First, U.S. paving contractors have been very reluctant to assume greater risk. Second, the Federal Government places certain legal restrictions on warranty use. Third, performance testing requires further development so methods are proven accurate and test results can be used to legally invoke warranty clauses. Finally, the surety industry may have the largest say in the extent to which performance based incentives will be adopted in the United States. Transportation agencies commonly limit their risk by requiring a contractor be bonded. Bonding agencies may or may not be willing to accept the risk associated with a two to seven year performance warranty. Sureties are especially wary when contractors have little to no say in pavement design and no control over post-construction pavement use (WSDOT 2002).

A few state highway agencies have used both asphalt concrete and Portland cement concrete pavement warranties for many years. Under a pavement-warranty specification, quality is measured by the actual performance of the pavement as opposed to the properties of pavement materials and methods of construction. Pavement warranties require the construction contractor to guarantee the post-construction performance of the pavement. The shifting of post-construction performance risk from a state highway agency to a contractor is perceived to reduce premature pavement failures, reduce costs, and increase pavement quality. However, for most contractors to feel comfortable with assuming the increased risk associated with a pavement warranty, some type of monetary incentive must be provided (TRB 2005a).

Some states that use pavement warranties have reported a reduction in costs and an improvement in quality, while others have not. For example, the Wisconsin DOT has reported a significant quality increase and overall cost reduction through the use of five year performance warranties for asphalt concrete pavements (TRB 2005a). However, an evaluation of three year workmanship and materials warranties completed by the Colorado DOT showed no discernible impact on quality or cost (TRB 2005a).

2.6 Other Initiatives toward Management of Long-Term Pavement Performance.

The Oregon Department of Transportation (ODOT) currently uses Incentive/Disincentive (I/D) contracting on a project-by-project basis. Currently, the selection process is proactive towards the needs of each project rather than a standard procedure based on a set of established guidelines. ODOT is attempting to develop a process to assist the selection of I/D contract methods with associated values and timeframes based on guidelines or standards that have been developed within the construction industry. With the continued evolution of using both insourced and outsourced project delivery at ODOT, the I/D process needs to be flexible, encompassing a wide range of problems and issues associated with both preliminary engineering and construction engineering. The implementation of such a process will require substantial support and documentation. The information will need to be highly organized and articulate the elements of cost, schedule, quality and public support associated with a particular I/D clause (TRB 2004).

Washington State Department of Transportation (WSDOT) has used various incentives in paving contracts for many years but reached no conclusion as to whether incentives influence the quality or outcomes of a project. An assessment of performance based contracting is currently examining the bidding process, impacts on contractors and agency personnel and project outcomes. This research will assist WSDOT in determining whether to increase or decrease the use of performance incentives in WSDOT pavement contracts (TRB 2005b).

A research project is currently investigating the effectiveness of using alternative contracting techniques on Florida Department of Transportation (FDOT) construction projects. The research is comparing relevant performance factors for traditional Design-Bid-Build projects with those of the following alternative contracting techniques: A+B, Incentive/Disincentive, Design-Build, No-Excuse Bonus, CM at Risk, and Lump Sum. The comparison will include the overall delivery from concept to completion for each technique. The specific performance measures to be considered are comparison of initial estimates, contractors price proposal, final estimate, original contract time, final contract time, project quality, overall value, and administrative costs. The desired outcome of this research is a definitive statement on the applicability of alternative contracting techniques on FDOT construction projects. Additionally, this research is evaluating strategies intended to standardize the alternative contracting techniques, including training opportunities (TRB 2006).

State departments of transportation are under increasing pressure to reduce the duration and cost of highway construction projects. This pressure stems from the desire to reduce traffic delays and other inconveniences to the traveling public. To reduce the duration of construction projects, many state highway agencies have turned to the use of time-related incentive and disincentive contract provisions. A better understanding of the use of time-related incentives and disincentives in highway construction contracts is needed. Specifically, the following items require further research:

(1) The types of time-related incentive and disincentive contract provisions used in highway construction contracts and the extent to which they are used.

(2) The success of time-related incentive and disincentive contract provisions.

(3) Criteria used to determine when time-related incentive and disincentive contract provisions are appropriate and criteria to select the most appropriate provisions.

(4) Methods used to determine the dollar amount of the time-related incentives and disincentives.

(5) The effects of time-related incentives and disincentives on project completion. The objective of this research is to develop recommendations for effective use of time-related incentive and disincentive provisions in highway construction contracts (TRB 2005c).

CHAPTER 3
ANALYSIS

According to the National Cooperative Highway Research Program, true "performance-related standards":

- are based on properties of the finished product, not on the processes used to produce it;
- consider the variability inherent in the finished product and in the testing processes;
- are based on attributes that have been related to the actual performance of the product through validated quantitative models;
- incorporate sampling and testing procedures whose combined costs are consistent with the importance of the quality benefit being sought; and
- make the contractor's payment dependent on how close the product comes to the level of acceptable quality (Volokh 1996).

3.1 Proposed Pavement Performance Incentive Program

Parameters used to measure the quality of long-term pavement performance must be understood by both construction personnel and the NDOR's quality control technicians. Guidelines with regard to which parameters should be evaluated for inclusion in the NDOR's performance-based incentive program included the following:

- Parameters should be one or more of those performance indicators currently being measured by the NDOR. The NDOR measures a variety of performance indicators including various cracking indices, IRI, PSI, NSI, etc.
- Parameters must correlate to an acceptable level of pavement performance at the time when the incentive will be assessed.

The research team originally proposed two sets of parameters, one for conventional flexible pavement and the other for Superpave, as shown in Table 10. Table 10 was subsequently discussed with representatives from Dobson Brothers, Hawkins and Werner Construction at the University of Nebraska on November 17, 2006.

Table 10 – Initial Performance-Based Incentives Proposed for Asphalt Pavement

	Eligibility Criteria	Incentive Parameter	Payment - % of Contract
Asphalt (Traditional)	Profile Index ≤ 8 inches/mile Variance of asphalt binder content from design content (%) ≤ 0.25	IRI ≤ 1.00 mm/m @ 2 yrs IRI ≤ 1.2 mm/m @ 4 yrs Rutting ≤ 4 mm @ 2 yrs Rutting ≤ 4 mm @ 4 yrs	2.5 % @ 2 yrs 2.5 % @ 4 yrs 2.5 % @ 2 yrs 2.5 % @ 4 yrs
Asphalt (Superpave)	Dynamic Shear(Original) ≥ 0.89 KPa Dynamic Shear (Residue) ≥ 1.95 KPa Creep Stiffness ≤ 315 MPa Creep Slope ≥ 0.291 Elastic Recovery ≥ 54 %	IRI ≤ 1.00 mm/m @ 2 yrs IRI ≤ 1.2 mm/m @ 4 yrs Rutting ≤ 4 mm @ 2 yrs Rutting ≤ 4 mm @ 4 yrs	2.5 % @ 2 yrs 2.5 % @ 4 yrs 2.5 % @ 2 yrs 2.5 % @ 4 yrs

Comments from the contractor representatives included:

a. Four or five years is too long for contractors to wait for payment. Long-term performance of asphalt pavement can be reliably estimated after two or three years.
b. Variance of asphalt binder content is probably not a good measure of quality of HMA pavement.
c. Performance should be based upon measurements taken from the driving lane only. Bridges, off/on ramps, etc. should be excluded.
d. Payment should be based upon $/SY of materials placed during construction instead of a percentage of the overall contract or tons

of material emplaced. Payment should be proportional to the cost of emplacing all layers (subgrade, base and wearing courses).

e. The NDOR contracts for more partial depth rehabilitation/ reclamation projects rather than full depth. Researchers had included full-depth replacement as a subcategory under traditional asphalt. Proposed standards should be expanded to include all rehabilitation projects.
f. Contractors would like to see a sample of flexible pavement projects completed, NDOR's assessment of quality of those segments upon completion, and hypothetical payments contractors would receive based upon proposed performance parameters measured two or three years later.

3.2 NDOR Suggested Modifications

Researchers then met with NDOR representatives from Materials and Research Division and Construction Division on December 1st, 2006. Comments from the NDOR personnel present at that meeting included:

a. All asphalt pavement contracted by NDOR must now meet Superpave specifications, so traditional asphalt as a category could be deleted from the proposal.
b. A discussion was held on the proposed standards of quality, specifically indicators for measuring pavement performance and whether IRI is indicative of quality for asphalt pavement. The consensus was that IRI decreases as asphalt pavement ages, so IRI is irrelevant for measuring long-term quality.
c. A similar discussion ensued reference cracking of asphalt pavement. The consensus was that control of cracking is beyond control of the contractor (at least for many applications of asphalt pavement). Cracking may or may not be affected by quality of

materials used or by “laydown” procedures. It should not be included as an indicator when measuring long-term pavement performance.

d. Flushing was subsequently discussed. Consensus was that flushing is affected by quality and quantity of binder used. However, flushing is not an indicator normally measured by the NDOR. The NDOR has no published standards concerning what levels of flushing are acceptable and what levels are considered excessive. Flushing in excess of 20% was thought to be excessive, but how frequently a measurement of flushing should be obtained for a given section of highway and method of documentation could not be agreed upon. The intent of this incentive program is to provide incentives only for factors which the contractor can directly control during the construction process. Flushing may or may not be under contractor control. Specific pavement segments will have to be manually evaluated for flushing if flushing is included as a proposed incentive.

e. Rutting was the only proposed standard judged to be acceptable under a performance based incentive program. Six millimeters was considered too high for the limit and two years was considered insufficient time to measure performance. Consensus was reached that three years and four millimeters or less of rutting were acceptable standards of quality for a performance based incentive program.

f. An extended discussion then took place on whether the NDOR wished to have eligibility criteria listed or whether the only eligibility criteria should be “selected by the NDOR”. Consensus was that the NDOR does not intend to apply these incentive standards to all or even to a majority of asphalt paving projects. Performance based incentives will be applied selectively only to specific projects where the NDOR has a special interest in contracting for long-term quality pavement.

g. Profilograph Pay Factor (PPF) and Material Pay Factor (MPF) were thought to represent good composite estimates of initial pavement quality. Projects with below-average PPF and MPF would not normally be eligible for performance-based incentives, so these factors could be used as eligibility criteria.
h. Consensus was that the same incentive(s) should apply to all asphalt pavement applications, whether new pavement, full or partial depth reclamation, rehabilitation or overlay.
i. The NDOR requested that performance indicators shown in Table 10 be condensed to reflect only one row of flexible pavement, with a standard of rutting $\leq$ 4 mm measured at three years. Flushing less than 20% was to be included in the final recommendation as well. PPF and MPF $\geq$ 100% should be listed as eligibility criteria. The proposed payment be based upon the NDOR's current practice of paying for quantity of asphaltic concrete (in tons or Mg) placed as surface layers, not as dollars per square yard (or per square meter) as requested by the contractor's representatives.

3.3 Analysis of Projects Where Materials and Workmanship Incentives Were Paid

Researchers then sought to investigate whether projects awarded incentives immediately after construction showed acceptable or better standards for long-term performance. The NDOR was asked to provide data for asphaltic concrete projects in excess of five miles in length, which had been constructed during the past three years, where quality incentives had been paid for smoothness and/or materials and workmanship upon completion of construction. Three years provided time for post-construction performance to accumulate and be measured while length in excess of five miles indicated a significant paving project. Rational for the quality incentive specification rested upon the assumption that a project which failed to earn an incentive for quality of construction would probably not be an ideal candidate for good long-term performance. Table 11 shows cost information concerning three asphalt paving projects approximately three years old that received materials and workmanship incentives from the NDOR for pavement quality. All projects involved Superpave specifications for asphalt. Three different types of construction incentives were paid for each project. Table 12 shows rutting measured for these three projects over the first three years of their lifespan.

Table 11 - Projects Where Construction Incentives Were Paid

Control Number	Smoothness Incentive Pay Factor	Additional Incentive Pay Factor	Quantity	Incentive Paid
Smoothness Incentive - Performance Graded (PG) Binder				
60937	Not Available	$5.94	776.92 Mg	$4,614.92
31345	104.06%	$6.46	522.08 Tons	$3,372.64
60893	100.75%	$2.04	248.298 Mg	$506.03
Smoothness Incentive – Asphaltic Concrete				
60937	Not Available	$0.84980	17,544.60	$14,912.91
31345	104.06%	$750000	12,733.75 Tons	$9,550.30
60893	100.74%	$0.14800	4,281 Mg	$633.59
Superpave Quality Incentive (Air Voids)				
60937	Not Available	$0.90	51,729.62 Mg	$46,400.99
31345	103.54%	$0.66	25,229.950 Tons	$16,651.77
60893	Not Available	$0.68	25,807.04 Mg	$17,419.75
Total Construction Quality Incentive Paid				
60937				$65,928.82
31345				$29,574.71
60893				$18,559.37

Table 12 – Analysis of Pavement Performance Over Three Years

HWY	BEG REF POST NUM	END REF POST NUM	CNTRL NUM	WRK DESC	DT COMP LTD	AVG RUT D 2003	AVG RUT D 2004	AVG RUT D 2005	AVG RUTD 2006	IRI 2006	CRK NG IDX
2	258.04	270.32	60937	GR CULV RESURF S-SHLD	2002	0.75	1.43	1.6	2.4	0.8	1.7
30	114.31	124.31	60893	GR STR RESURF	2003	0.3	3.39	3.58	4.6	0.9	0
275	31.91	39.31	31345	RESURF	2002	3.37	4.87	ND	4.5	1	5.5

CHAPTER FOUR
RESULTS

Based upon the meeting with contractor representatives, the meeting the NDOR's Materials and Research Division and Construction Division personnel, and analysis of information in Tables 11 and 12, a proposal for a performance-based incentive program for asphalt pavement was created and is summarized in Table 13. Researchers initially intended to recommend a 5% incentive based upon total cost of asphalt paving materials for the project. However, the incentive paid for construction quality varied on the three project analyzed from 3.7% to 5.7%. An incentive less than the construction quality incentive paid three years in the future would appear to be of little interest to most contractors, so a 6% payment was recommended instead. Six percent is only a recommendation. The actual percentage paid can be adjusted upward or downward by the NDOR until the level of interest displayed by contractors is sufficient to satisfy the NDOR's needs. Four millimeters of rutting during the first three years of pavement life remains the recommended standard based upon meetings with both contractor's representatives and the NDOR. Both the standard and/or the time period can be adjusted upward or downward as needs or conditions change.

Table 13 – Proposed Performance Incentive(s) for Asphalt Pavement

Asphalt Pavement Performance			
Eligibility Criteria	**Incentive Standards**	**When Measured**	**Payment**
Profilograph Pay Factor ≥ 100%	rutting ≤ 4 mm	3 yrs	~ 6 % of asphalt pavement cost as determined by the NDOR
Materials Pay Factor ≥ 100%	flushing ≤ 20% of paved surface		

Table 14 illustrates how the proposed performance based incentive would have applied to the three projects analyzed in Tables 11 and 12. Two of the projects would have been ineligible for the proposed performance based incentive as the measured value for rutting exceeded the maximum level three years into the pavement's lifespan.

Table 14 – Application of Performance Incentive to Three Projects

Highway Number	Control Number	Total Cost of Asphalt Paving	Distance (Miles)	Average Rutting at 3 Years	Proposed Performance Incentives
2	60937	$1,150,566	12.28	1.6	$69,034
30	60893	$505,205	10	4.6	$0
275	31345	$494,595	7.4	> 4.5	$0

The proposed pavement performance incentive was never envisioned as being applied to all projects but only to projects where the NDOR wishes the resulting pavement to be of superior quality. These situations might include roads where the volume of traffic is sufficient to make repair and/or rehabilitation exceedingly difficult or costly.

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

Results of this research can be used by NDOR to provide contractors with incentives to more closely control the quality of materials used in mixes and methods of construction for asphalt pavements. Percentages or time periods associated with a specific incentive can be established by level of performance desired and adjusted to encourage the desired level of contractor participation in this process.

The performance incentive system proposed is designed to align the objectives of paving contractors more closely with the objectives of the NDOR. Under this system, both the NDOR and pavement contractors will be interested in providing pavement that meets certain specifications upon completion of construction and performs well enough to continue meeting established standards for a period of time afterward. This system will highlight to contractors the need to use quality materials and methods and will also provide a positive financial incentive in later years for contractors who construct quality pavement.

A quality incentive program of this type based upon pavement performance could become a nation-wide trend. Many state transportation agencies are experimenting with pavement warranties, best value contracts and performance based contracting procedures in an attempt to procure higher quality pavement. A quality incentive program of the type proposed in this research has the potential to provide most of the benefits of these three programs at less than cost and certainly with less legal entanglements.

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